Status and Assessment of the MODIS-like IR Absorption Channel Radiance Product for VIIRS based on VIIRS–CrIS Data Fusion

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Special thanks to:
Geoff Cureton[2], Greg Quinn[2], Yue Li[2], and Andy Heidinger[3]

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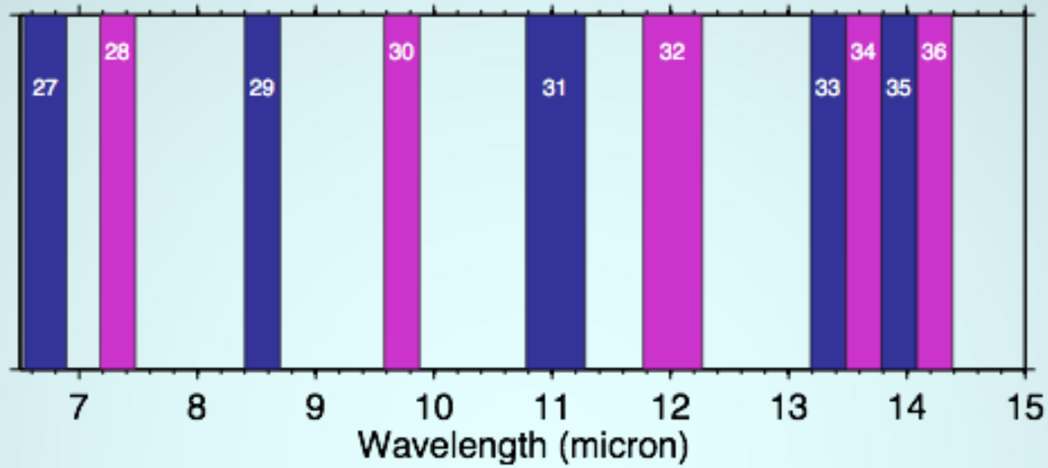
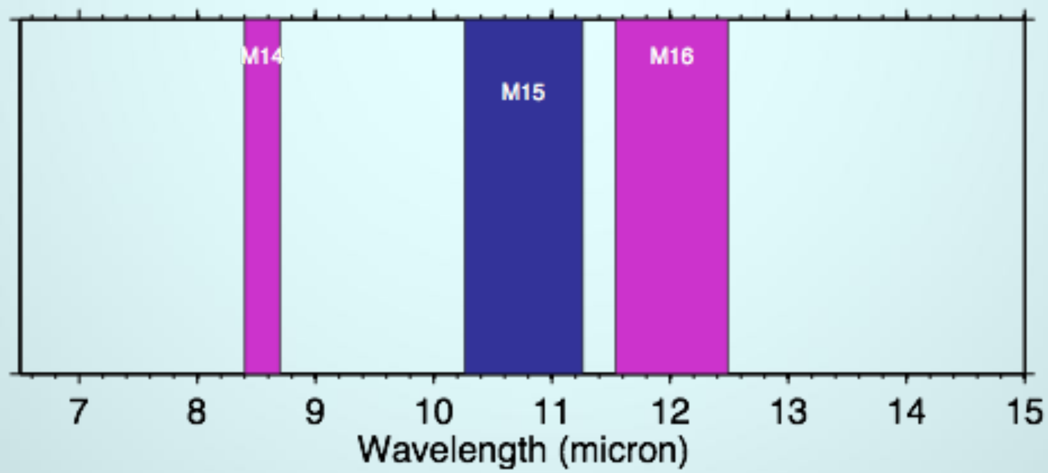
[3]NOAA/NESDIS/STAR, Madison, Wisconsin

CERES Science Team Meeting
April 30, 2020

VIIRS and MODIS IR spectral bands



MODIS



VIIRS

Project Summary

Our product provides VIIRS M-band (750 m) IR absorption band radiances based on imager-sounder data fusion (VIIRS+CrIS), for both Suomi-NPP and NOAA-20.

The IR absorption band radiances are constructed based on Aqua MODIS spectral response functions.

Achieve an order of magnitude increase in spatial resolution from sounder to imager at the cost of a small increase in noise compared to MODIS.

Fusion Approach

Step 1: Based on a relationship (*k*-d tree) between split-window imager pixel radiances (single pixel and average of pixels within a sounder FOV), find *N* sounder FOVs that best match a given pixel

Step 2: For each of the *N* sounder FOVs assigned to a given pixel, apply a set of spectral response functions (SRFs) to the hyperspectral radiances and calculate narrowband radiances

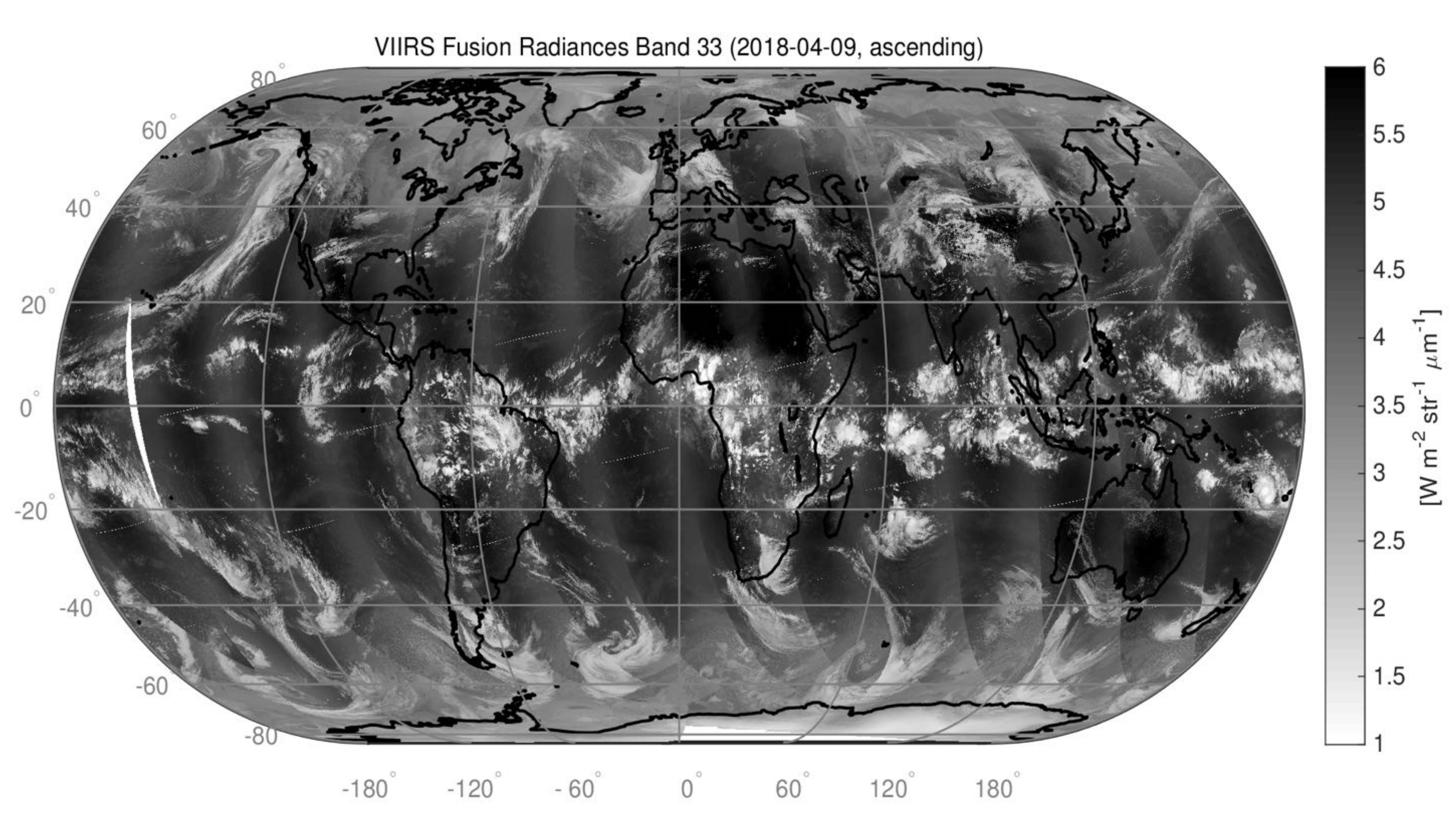
Step 3: Average the *N* narrowband radiances for each SRF and stamp on the pixel

Project: https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion/

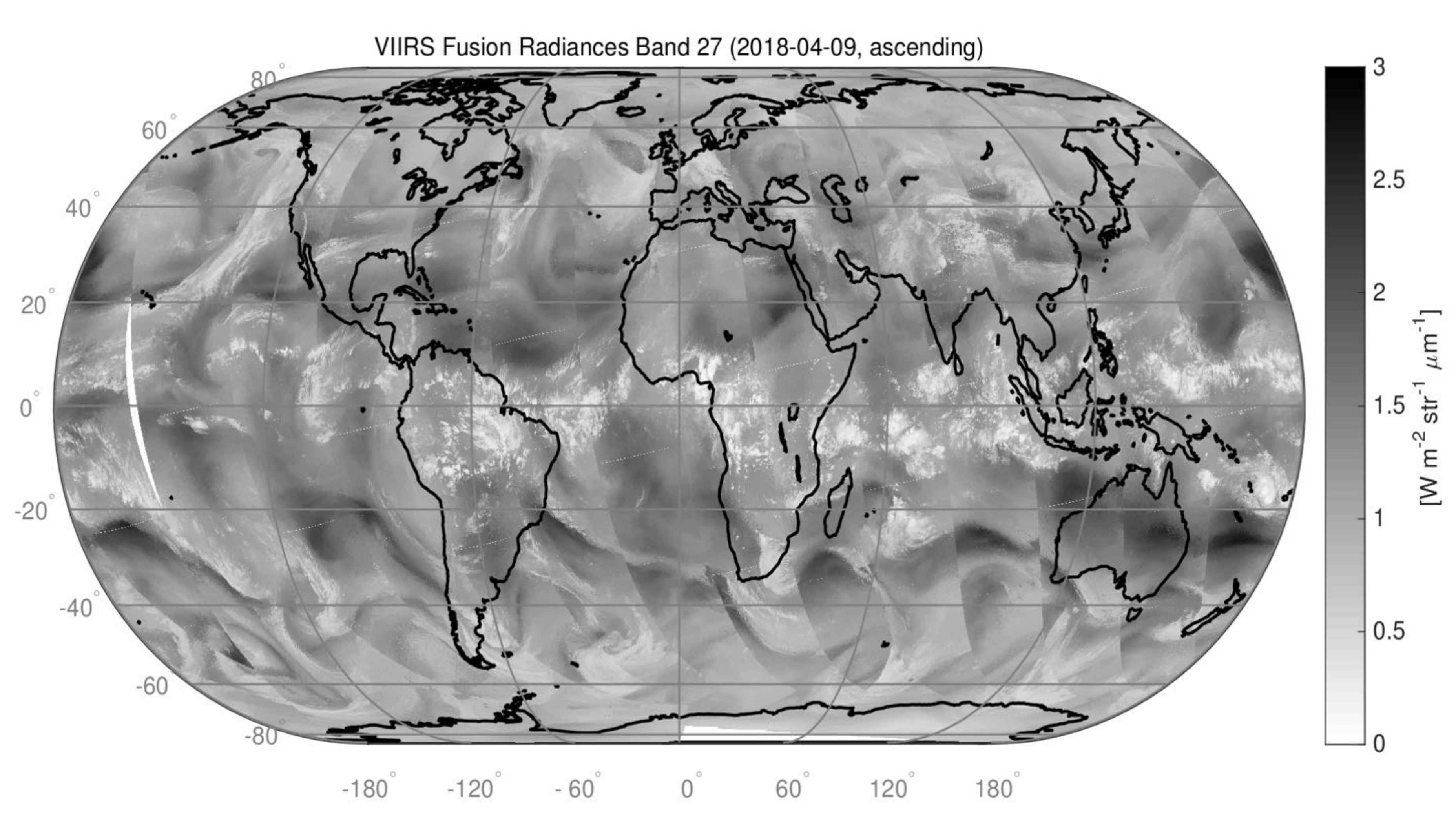
Cross et al., 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473, doi: 10.1117/1.JRS.7.073473.

Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. **11** (3), 036022, doi: 10.1117/1.JRS.11.036022

VIIRS/CrIS Fusion Radiances for 13.3-μm Channel



VIIRS/CrIS Fusion Radiances for 6.7-μm Channel



Fusion products are now operational for both S-NPP and NOAA-20: Search for "VIIRS CrIS data fusion"

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23,24,25, 27,28,30,31,32,33,34,35,36) are provided in a VIIRS Level 2 granule (NetCDF4).

Additionally, VIIRS (measured – fusion) brightness temperature differences are included for VIIRS M15 and M16 → Necessary for Optimal Estimation methods.

The VIIRS+CrIS Fusion product page (overview/documentation):

https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion

Direct access to the S-NPP VIIRS+CrIS fusion product archive:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5110/FSNRAD_L2_VIIRS_CRIS_SNPP

Direct access to the NOAA-20 VIIRS+CrIS fusion product archive:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5110/FSNRAD_L2_VIIRS_CRIS_NOAA20

Production Stats

For Suomi-NPP: the failure rate is < 2% since 2012 ; For NOAA-20: the failure rate is ~ 0.1%

Primary cause of failure corresponds with quarterly spacecraft maneuvers, but it appears that these are happening less often since first quarter 2019. This is less of an issue for NOAA-20.

2020 99% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Apr	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	24					97
Mar	100	100	100	100	98	100	100	100	100	24	0	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	93
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Jan	100	100	100	100	100	97	100	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99

2019 99% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Dec	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Nov	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100		99
Oct	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	82	99
Sep	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		99
Aug	100	100	100	100	100	100	100	100	100	100	99	100	98	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Jul	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Jun	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	86	92	100	100	100	100	100		99
May	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	99
Apr	100	100	100	100	98	73	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		99
Mar	100	100	100	100	100	100	100	97	100	100	100	100	100	100	100	100	98	100	24	0	85	100	100	100	100	100	84	100	100	100	100	93
Feb	94	100	100	100	100	100	100	100	100	100	98	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100				99
Jan	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	84	98	100	100	100	100	100	100	100	100	100	99

About the data fusion approach

Pros:

- No detector striping, out-of-band response, RVS, or other artifacts
- Same spectral response functions adopted for every JPSS platform
- Sounder data are very well calibrated
- Can apply the same retrieval algorithms to any platform with minor changes

Cons:

- Radiance differences increase outside of sounder swath but this can be mitigated by accounting for increased water vapor/CO_2 absorption
- Increase in noise around edges of rapidly changing radiance fields
- *May have more noise than an algorithm requires for accuracy*

VIIRS Fusion and Aqua MODIS Monthly Matchups for Suomi-NPP

Chris Moeller and Greg Quinn (SSEC/UW-Madison)

Global matchups are available over entire records of Suomi-NPP and NOAA-20

Analysis limited to matchups where only one VIIRS measurement falls within the MODIS pixel.

Matchups are filtered using the MODIS cloud mask (99% confident clear only).

Matchups include day+night, all surfaces

Each data point on the subsequent slides has at least 1,000 individual matchups, although most range between 10^5–10^6

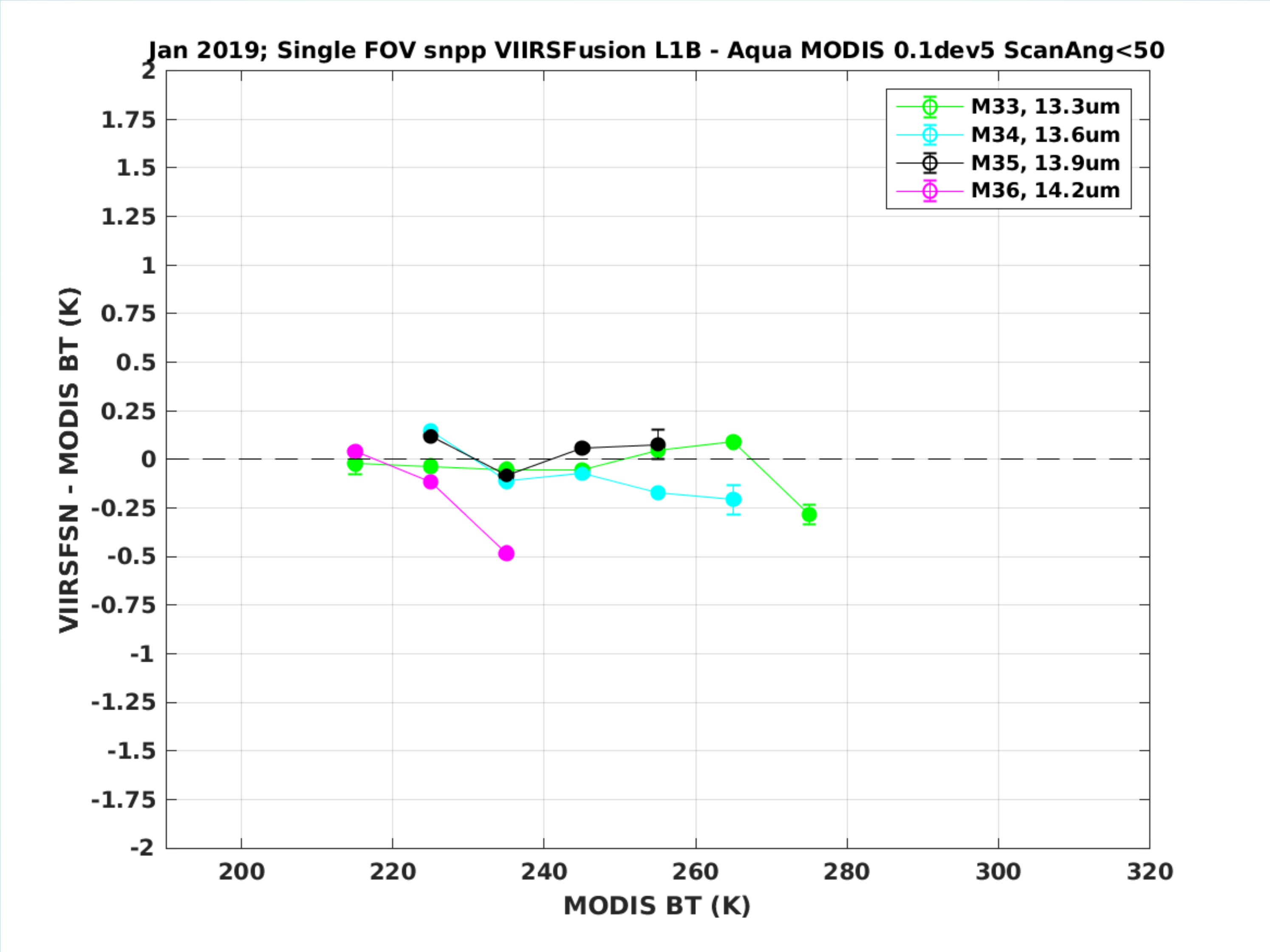
Establishing context for matchup results

Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required NE[Δ]T(K)[4]
Surface/Cloud Temperature	20	3.660 - 3.840	0.45(300K)	0.05
	21	3.929 - 3.989	2.38(335K)	2.00
	22	3.929 - 3.989	0.67(300K)	0.07
	23	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17(250K)	0.25
	25	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16(240K)	0.25
	28	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55(300K)	0.05
	32	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52(260K)	0.25
	34	13.485 - 13.785	3.76(250K)	0.25
	35	13.785 - 14.085	3.11(240K)	0.25
	36	14.085 - 14.385	2.08(220K)	0.35

S-NPP to MODIS Monthly Radiance Matchup Results for 2019

This effort was strongly encouraged by Rabi Palikonda and Pat Minnis at the fall 2019 CERES STM meeting

January 2019



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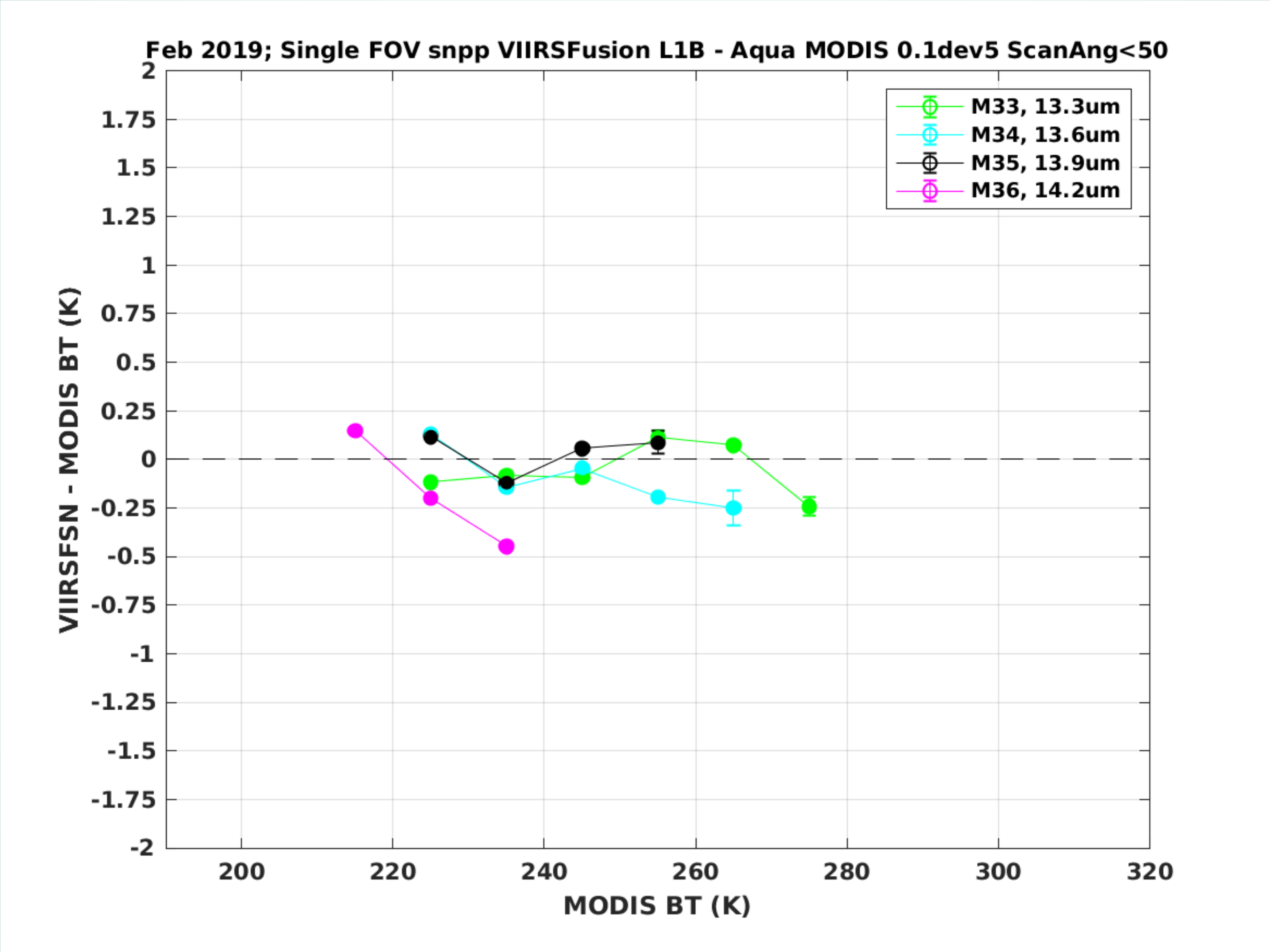

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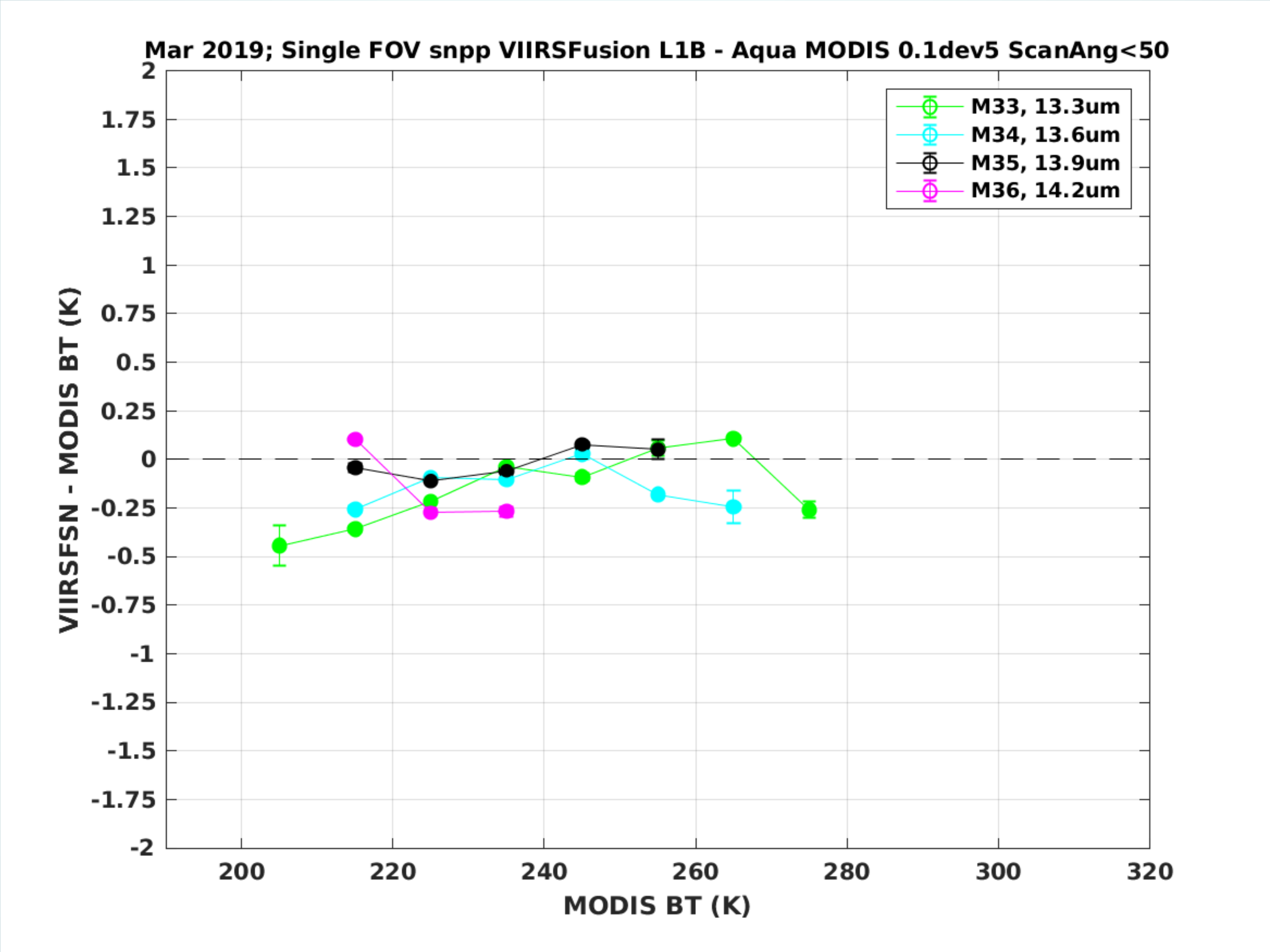

Mar 2019; Single FOV snpp VIIRSFusion L1B - Aqua MODIS 0.1dev5 ScanAng<50
M33, 13.3um
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M35, 13.9um
M36, 14.2um
VIIRSFSN - MODIS BT (K)
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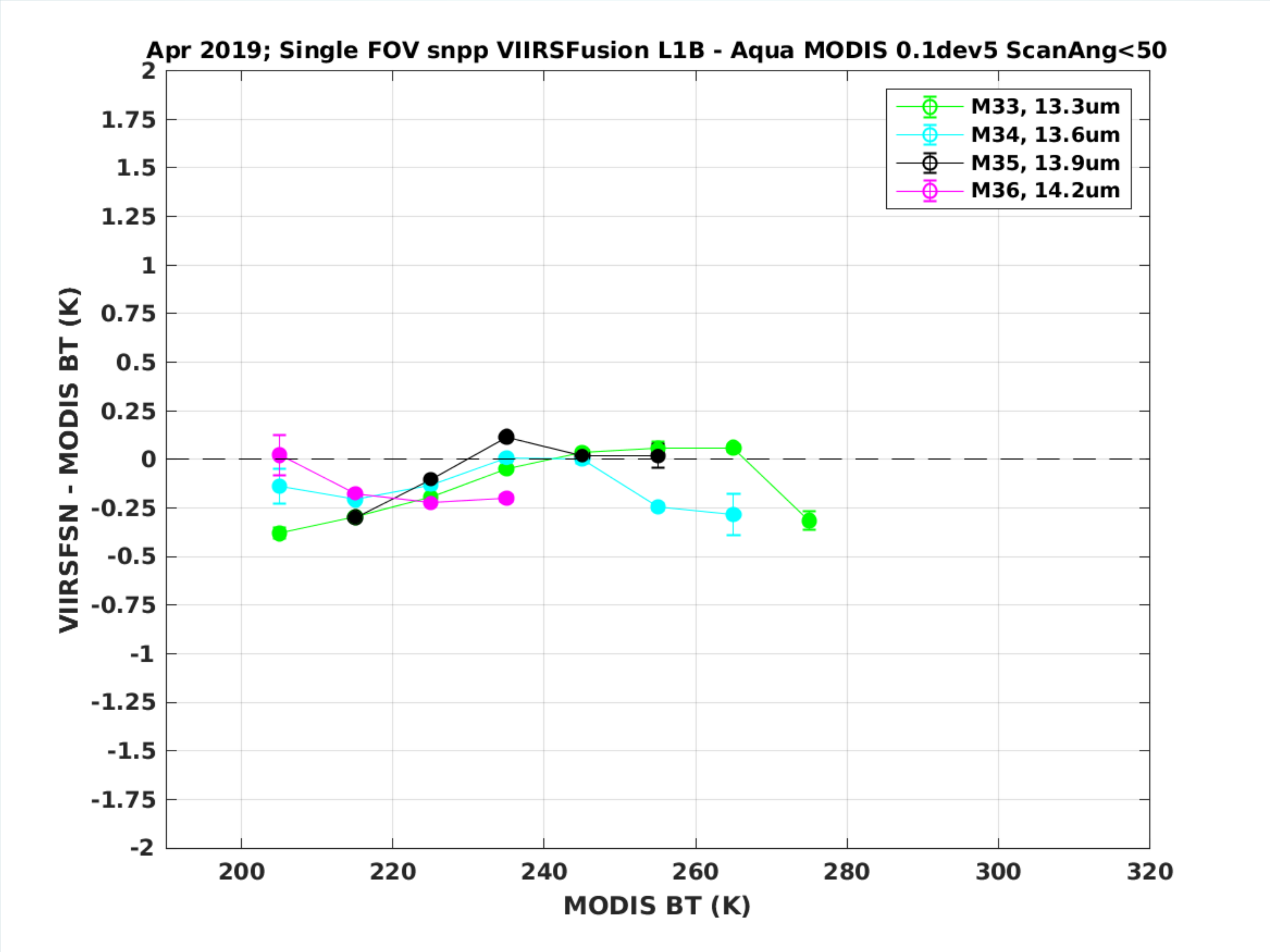
April 2019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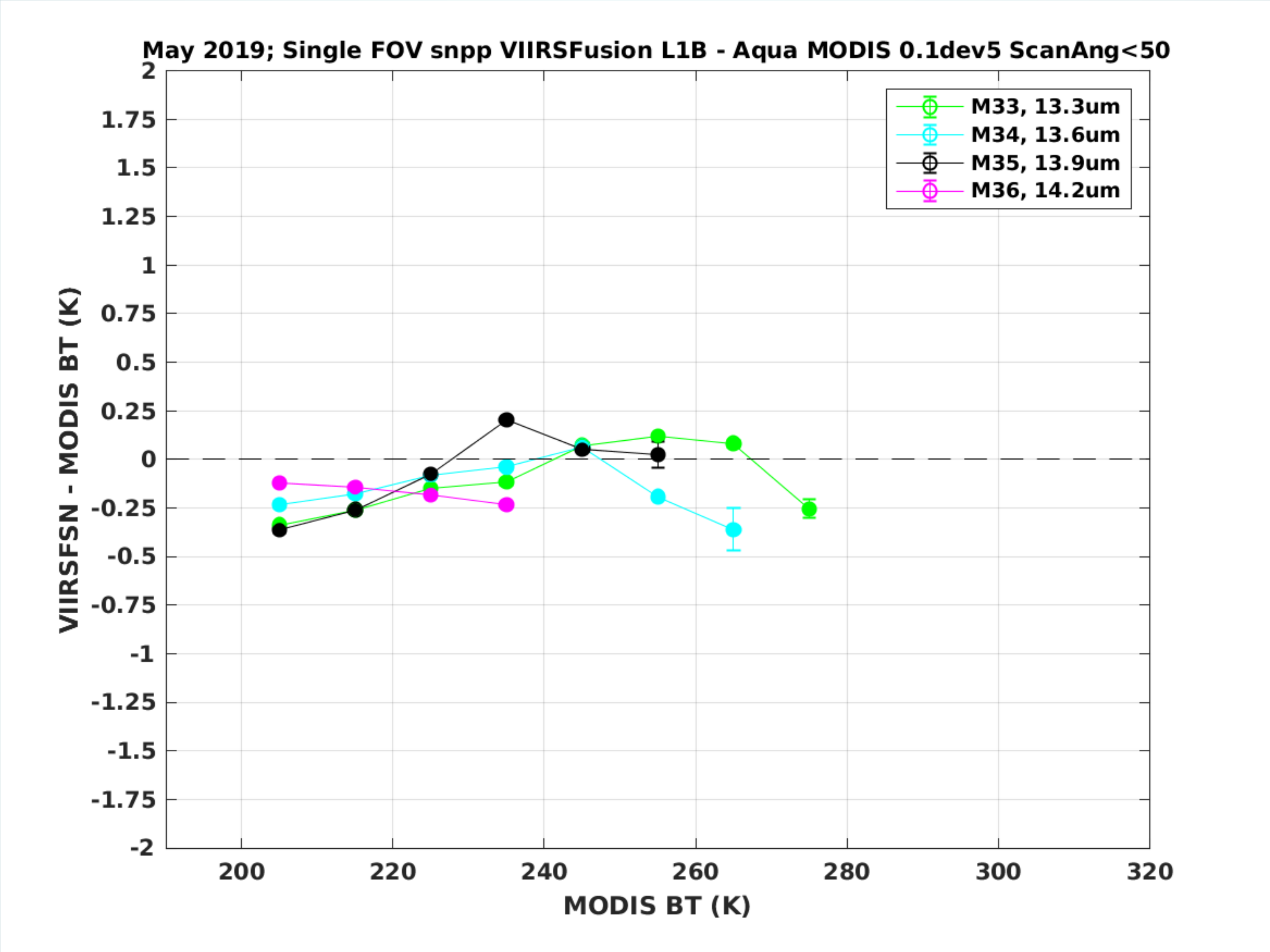
May 2019



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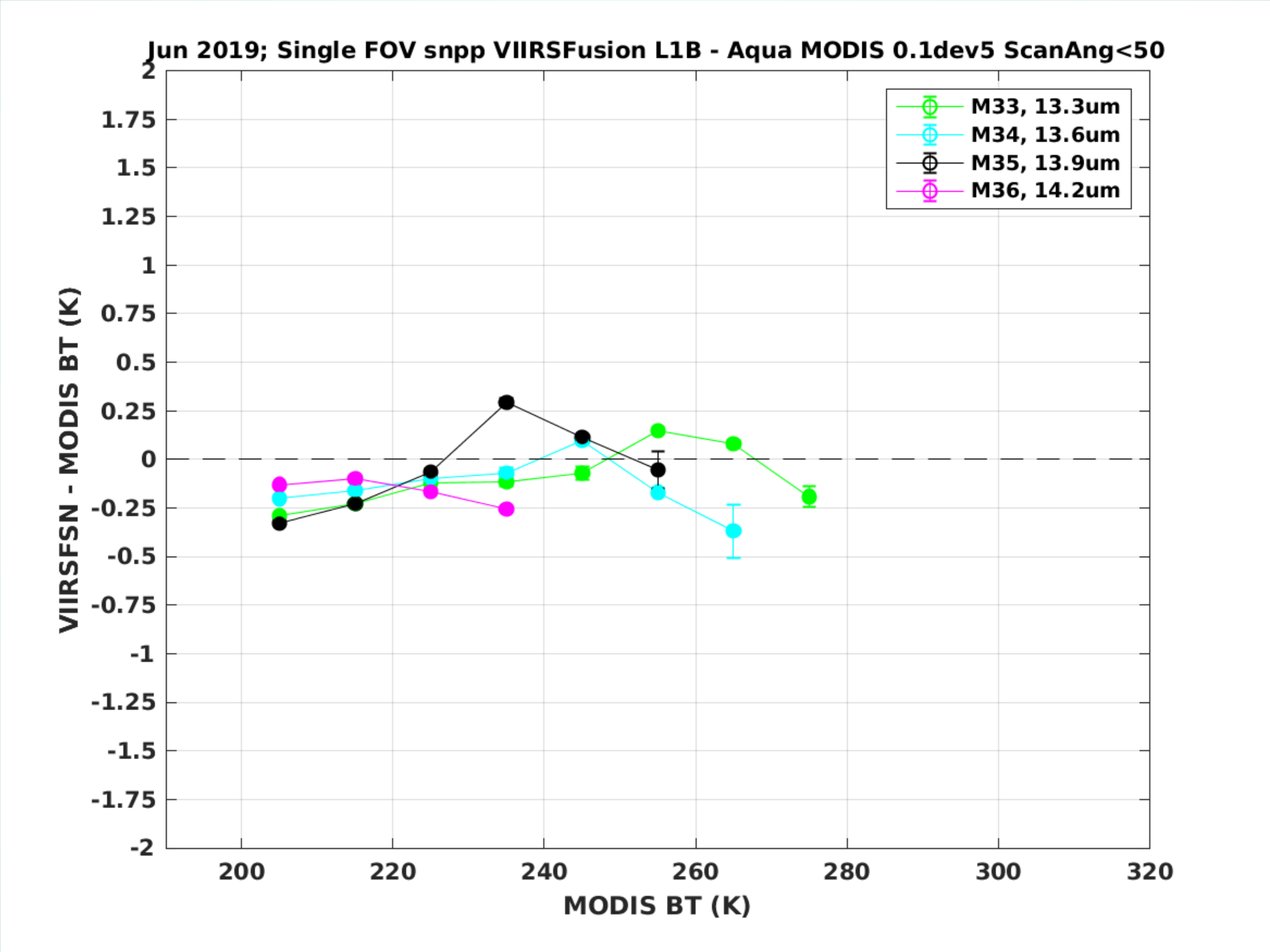
June 2019



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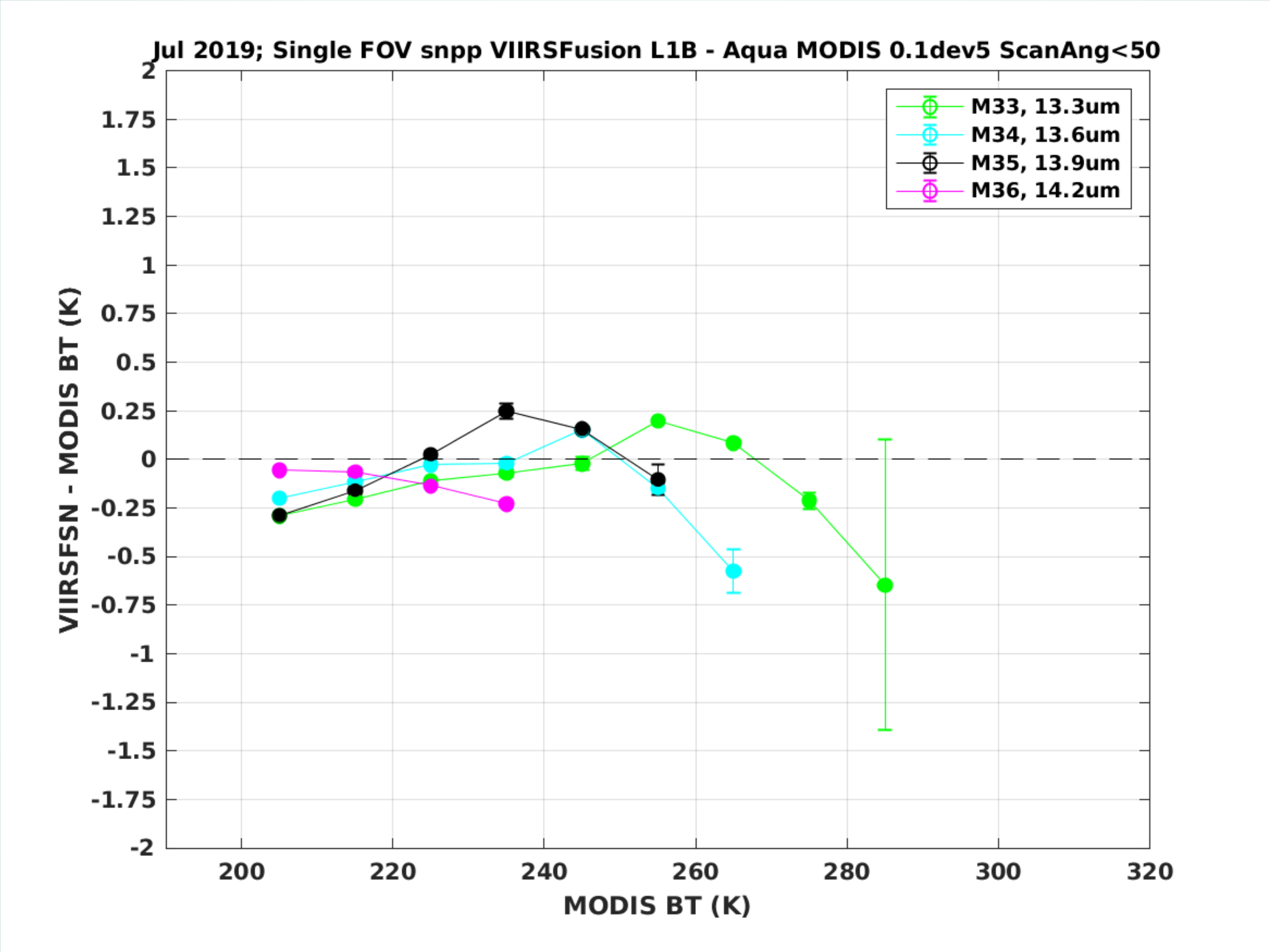

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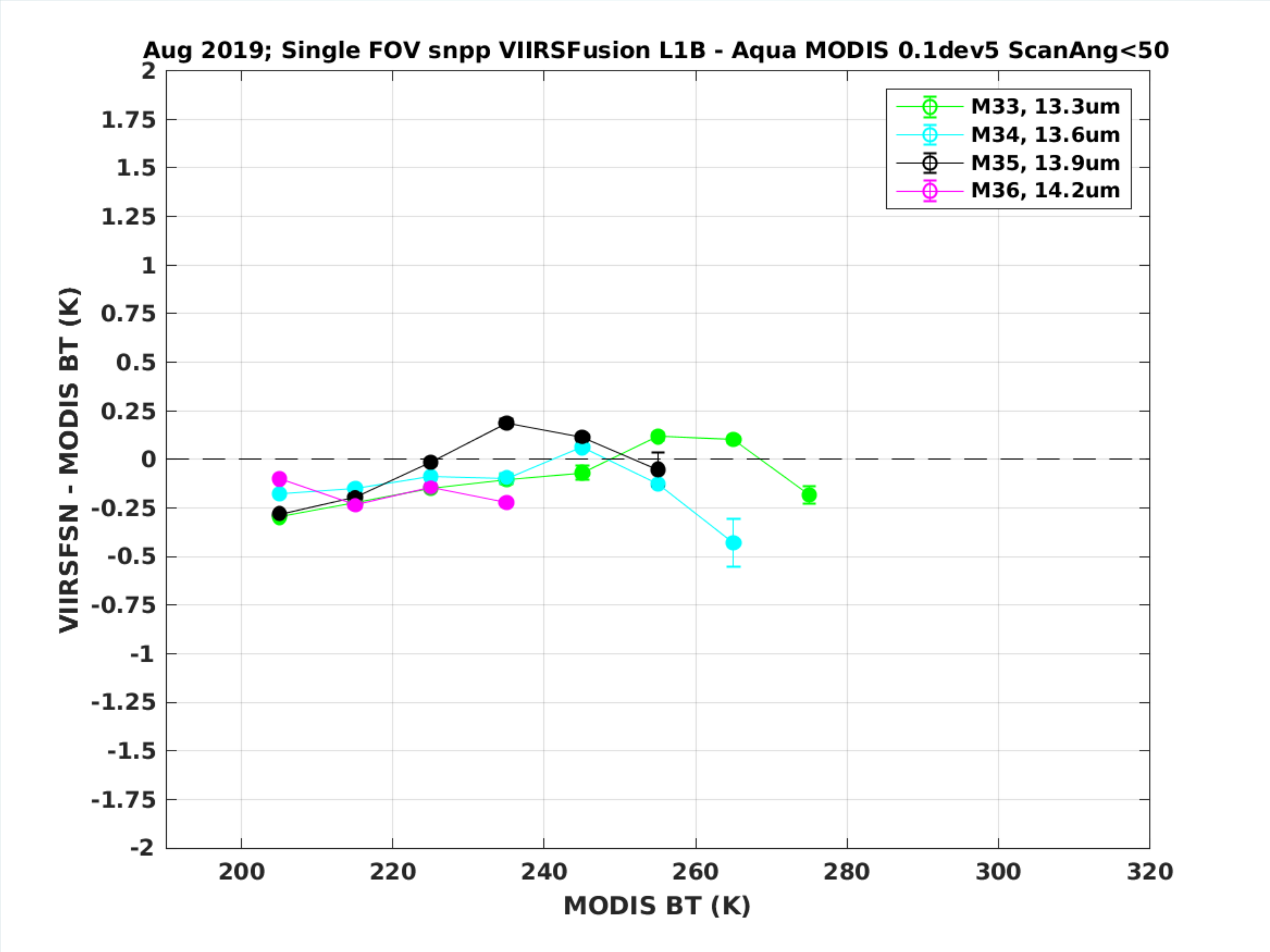
August 2019



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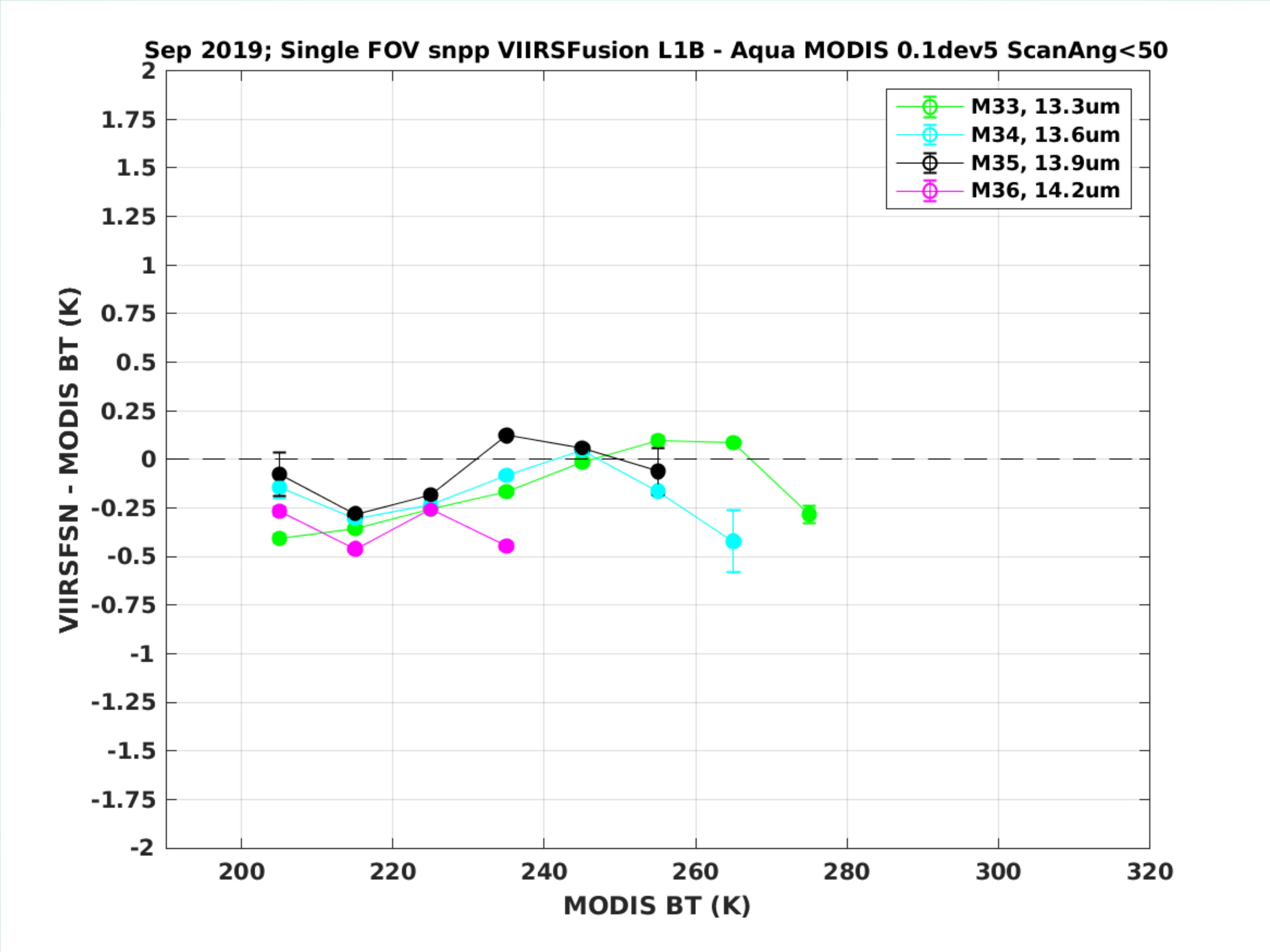

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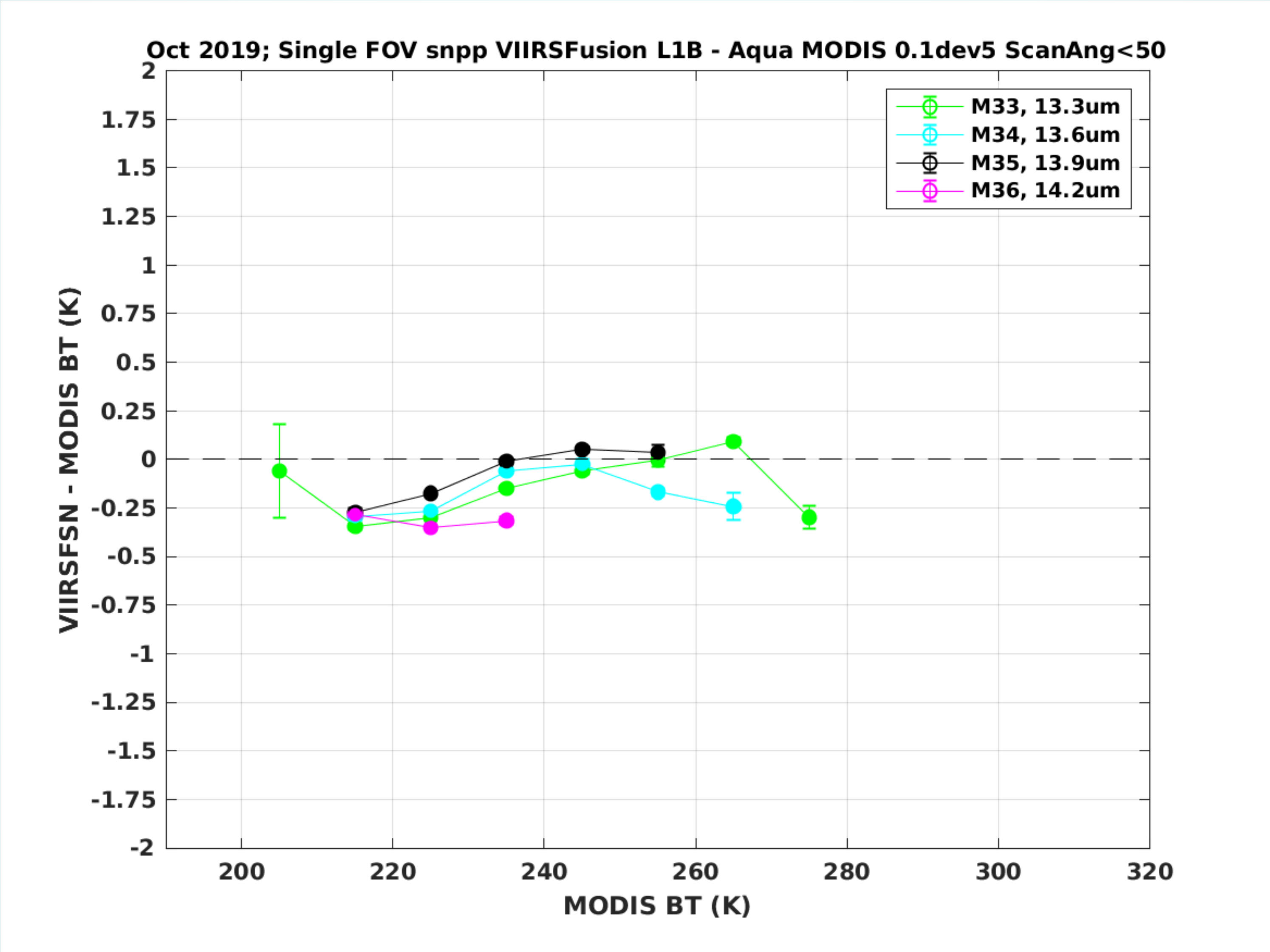

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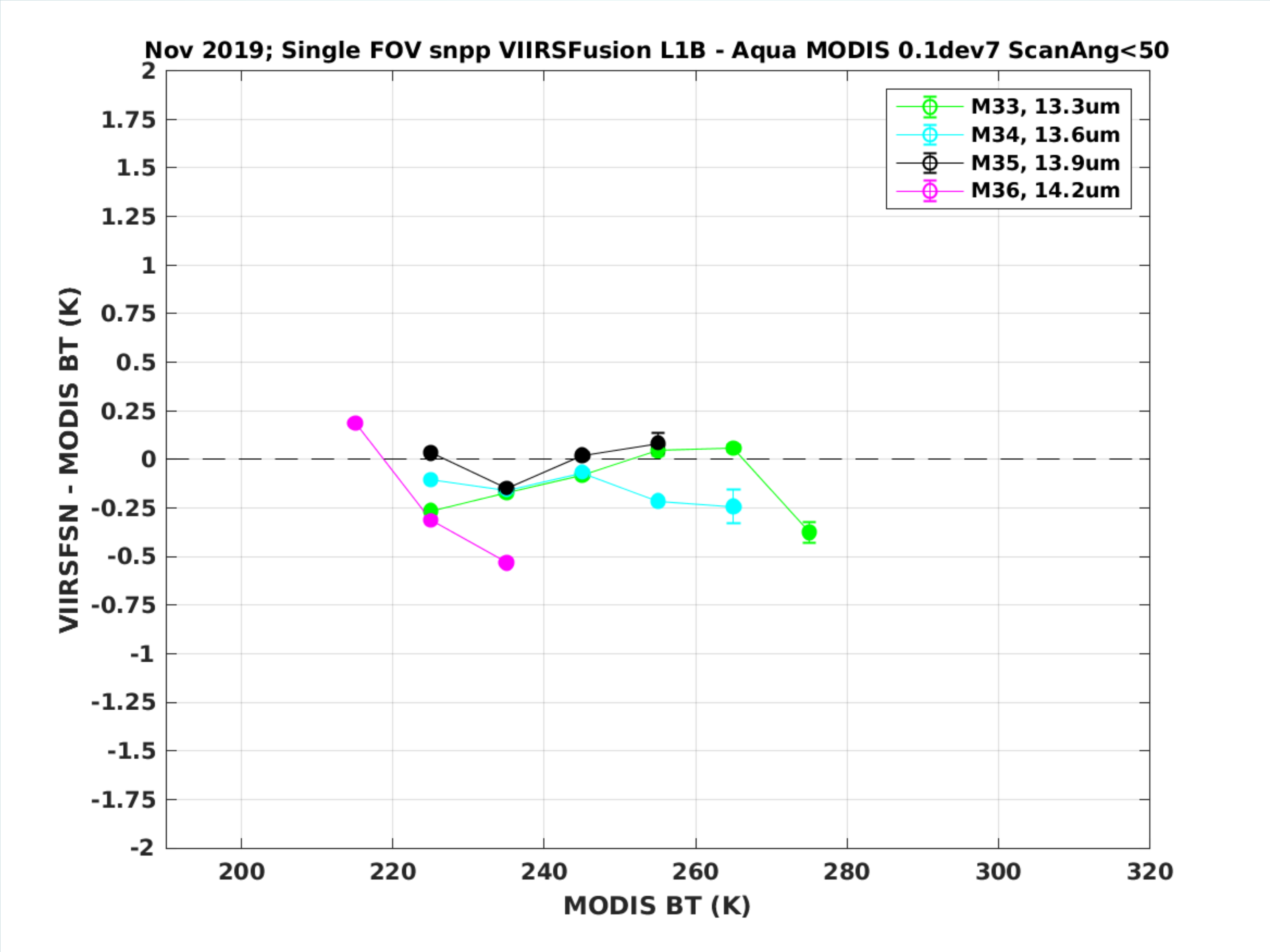

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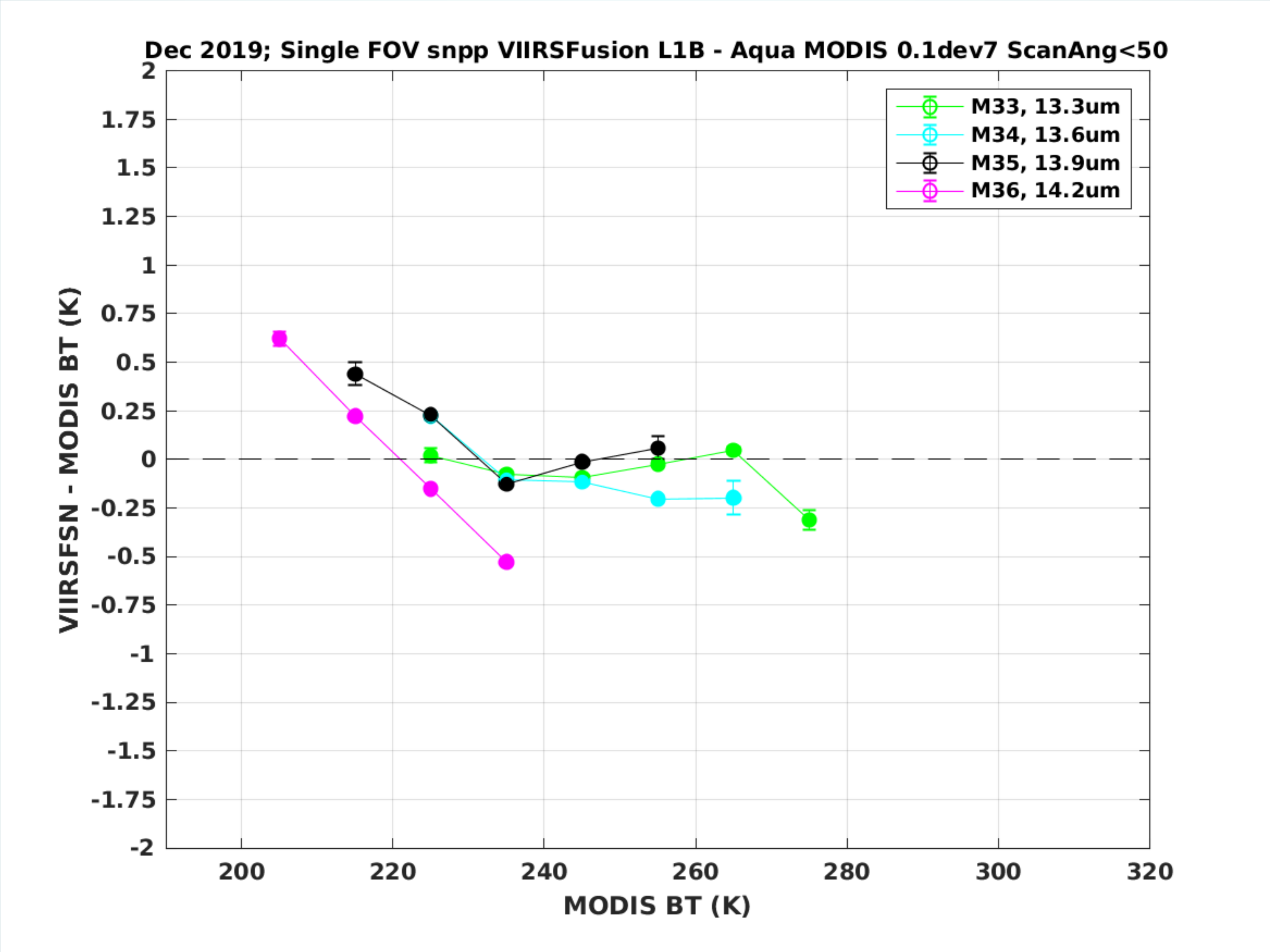
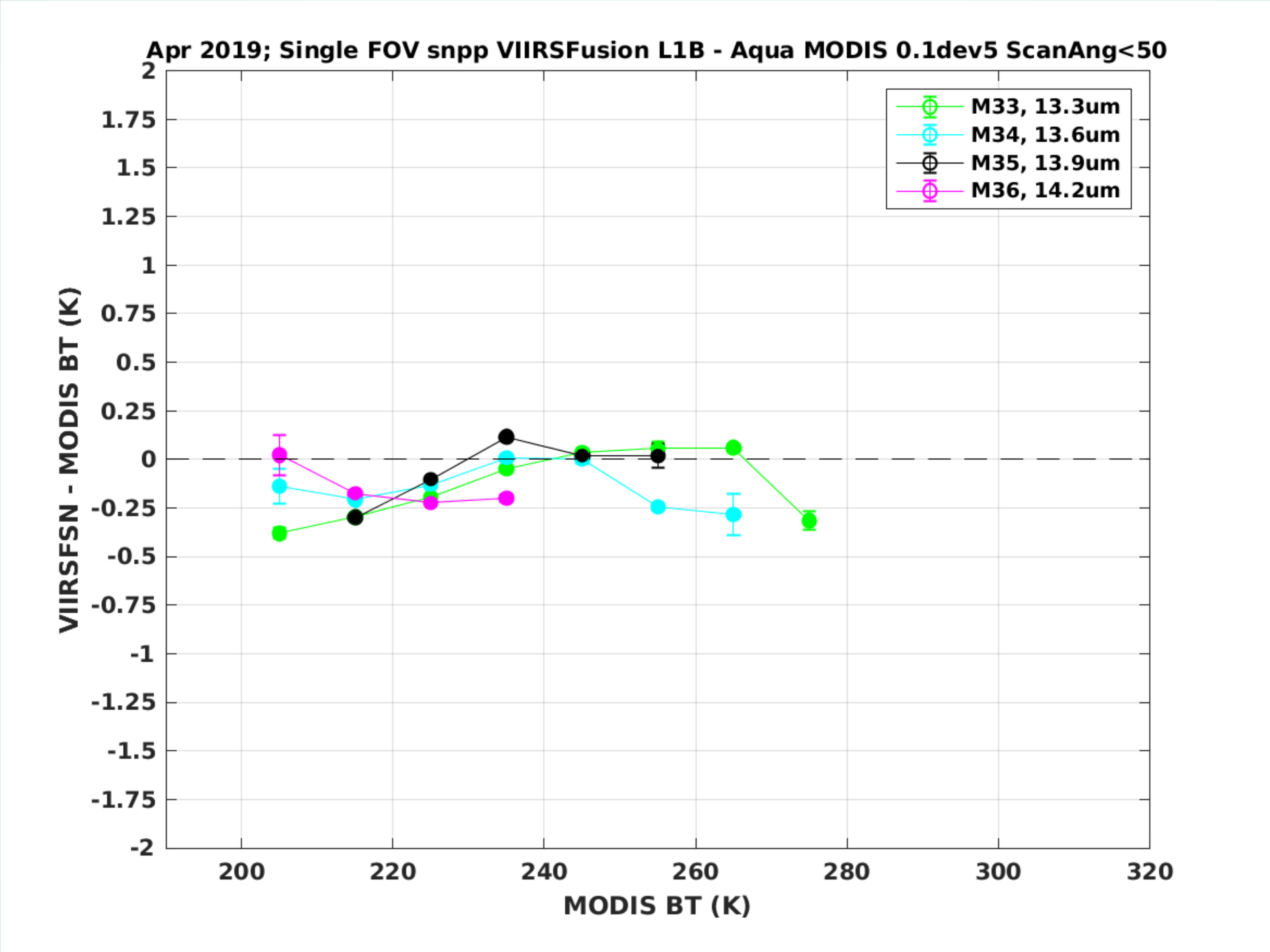


S-NPP Monthly Results for April Between 2012 and 2019

April 2019



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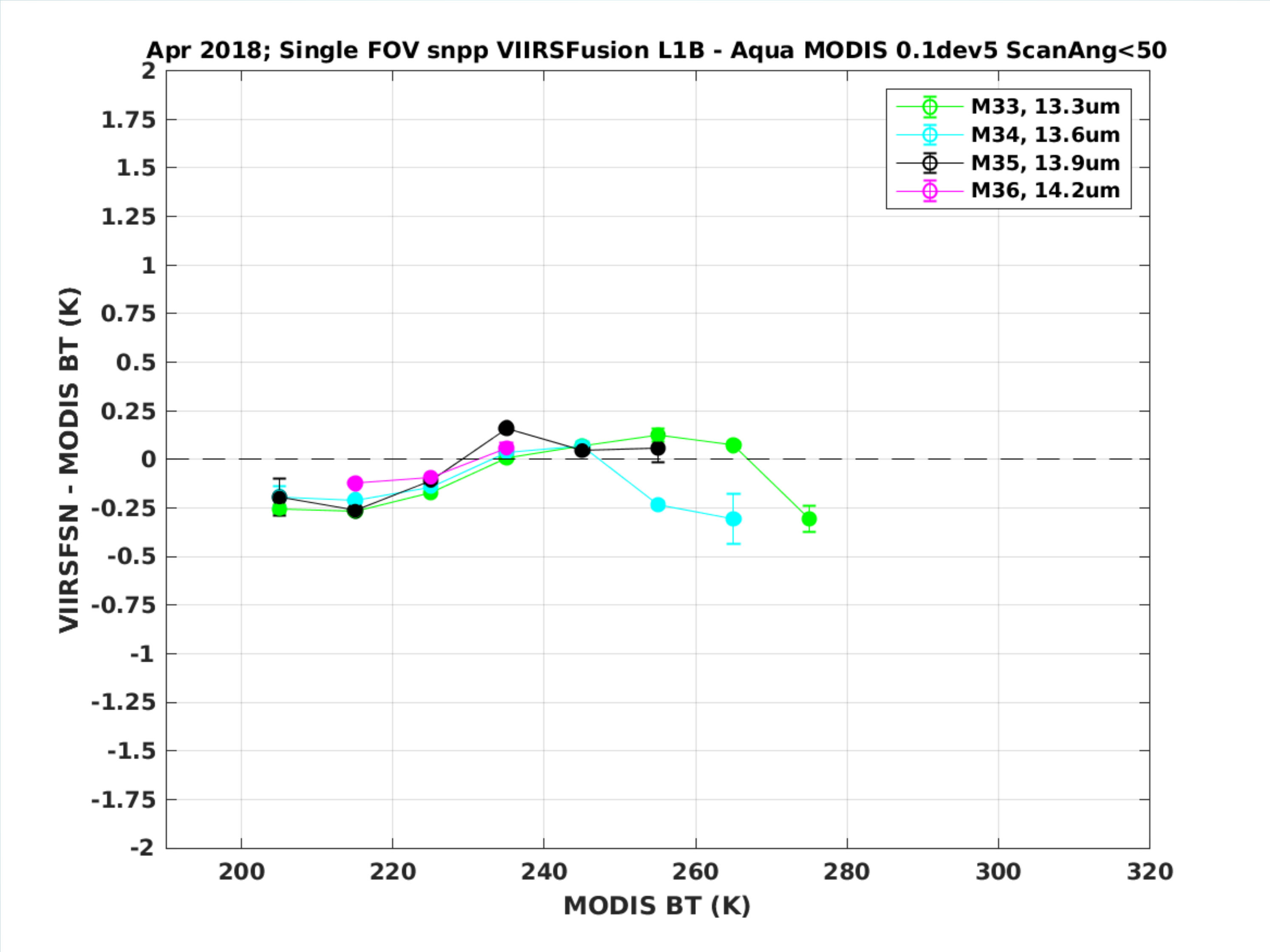

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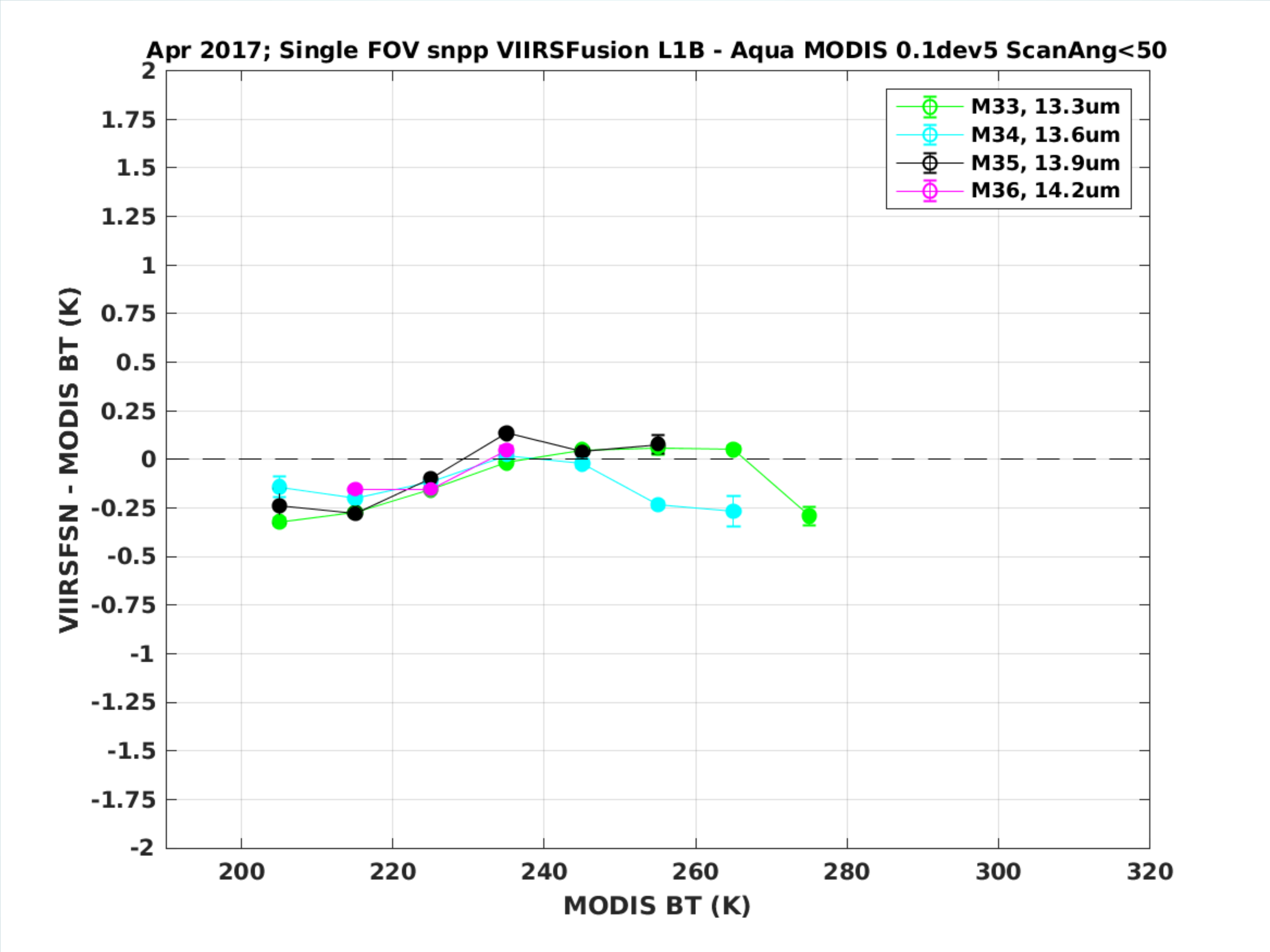
April 2017



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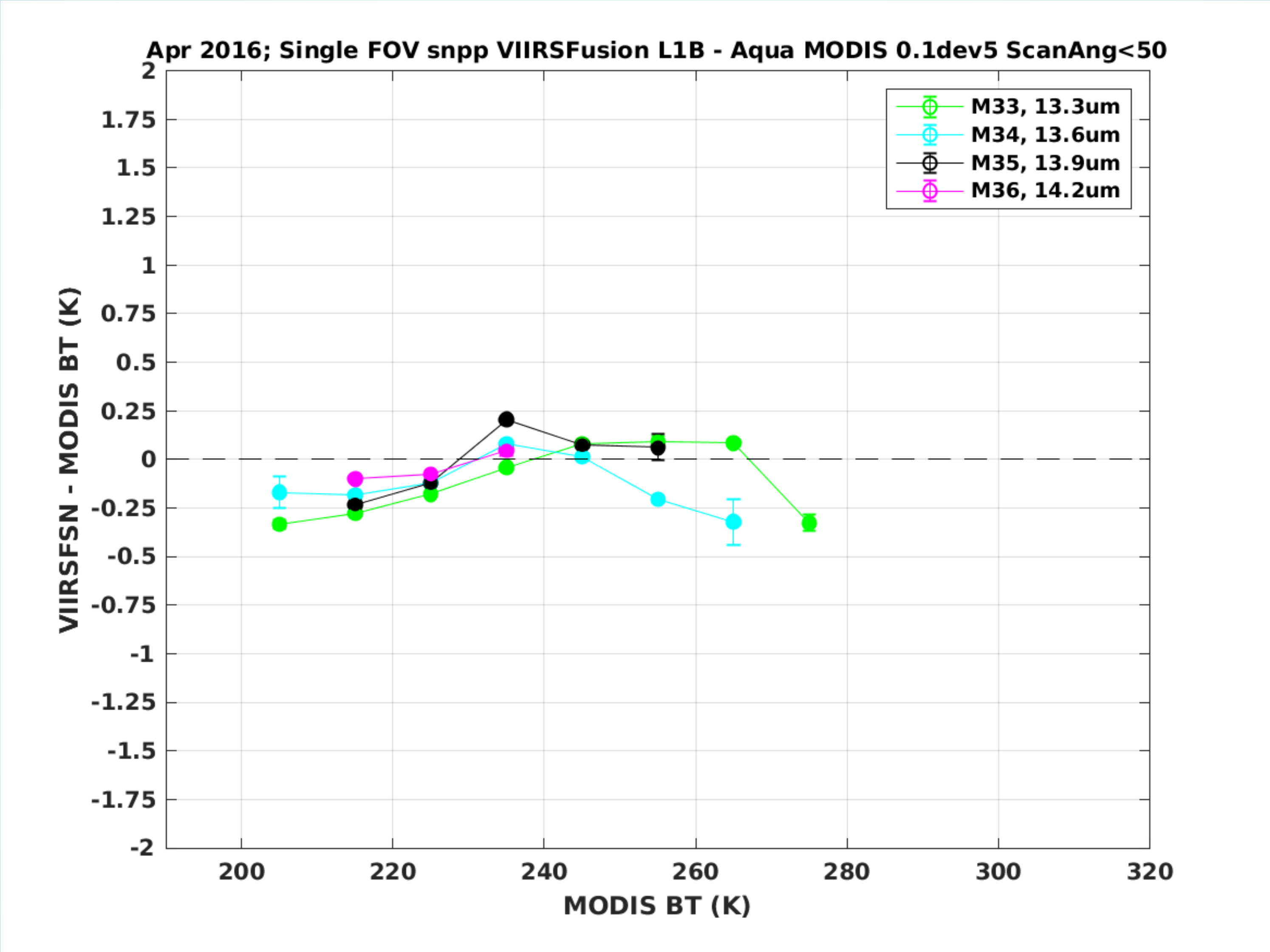
April 2016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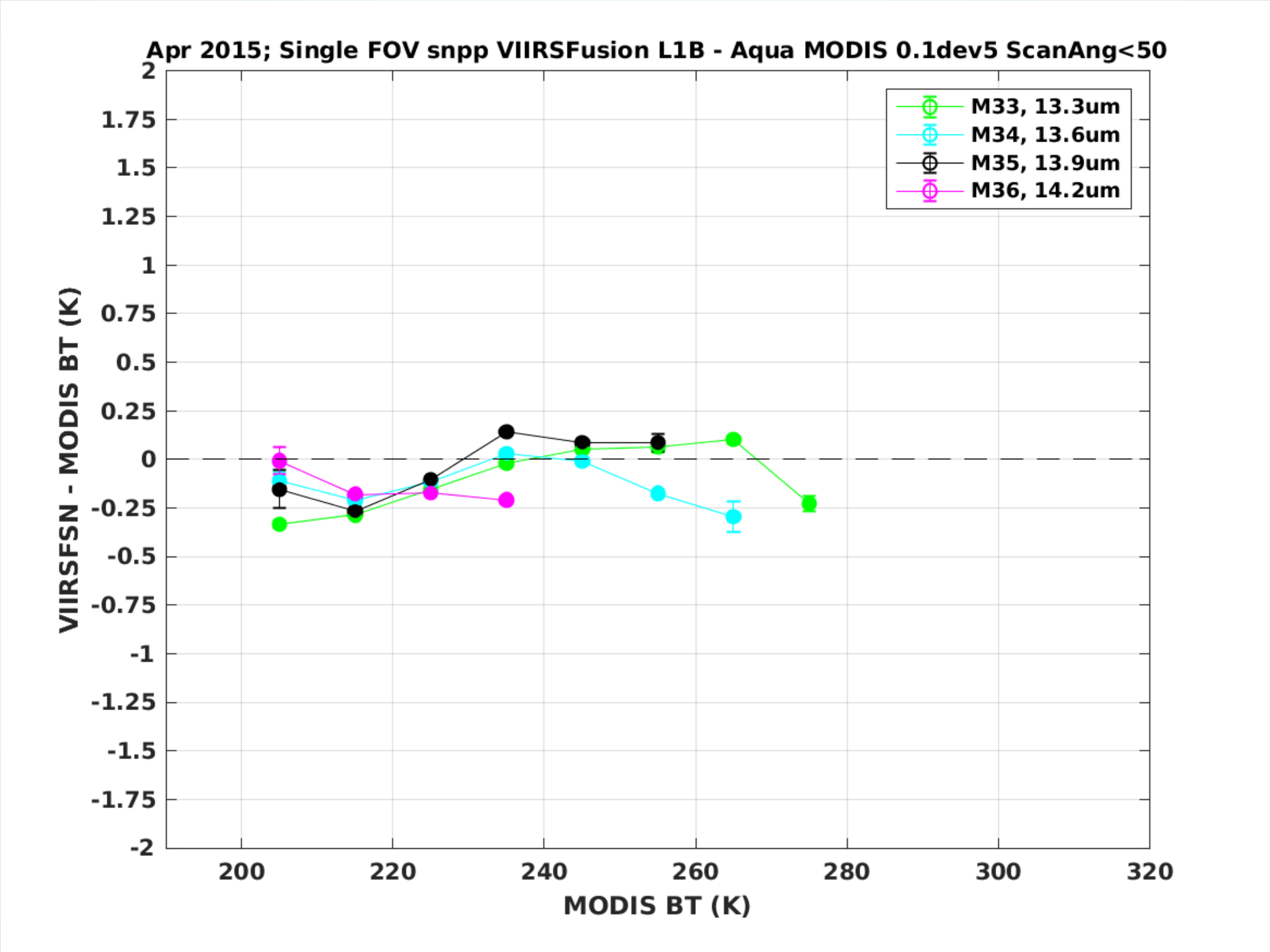
April 2015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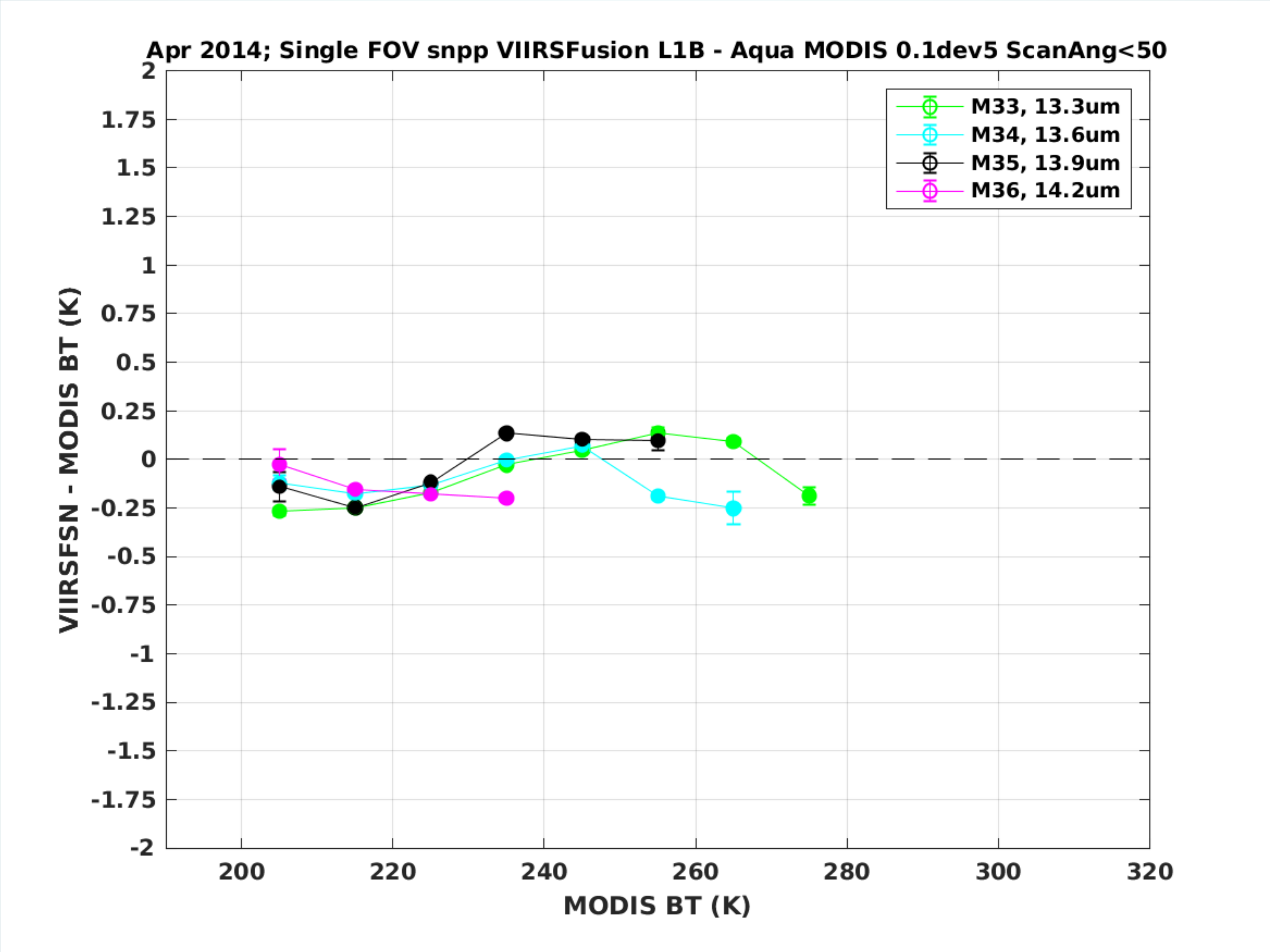
April 2014



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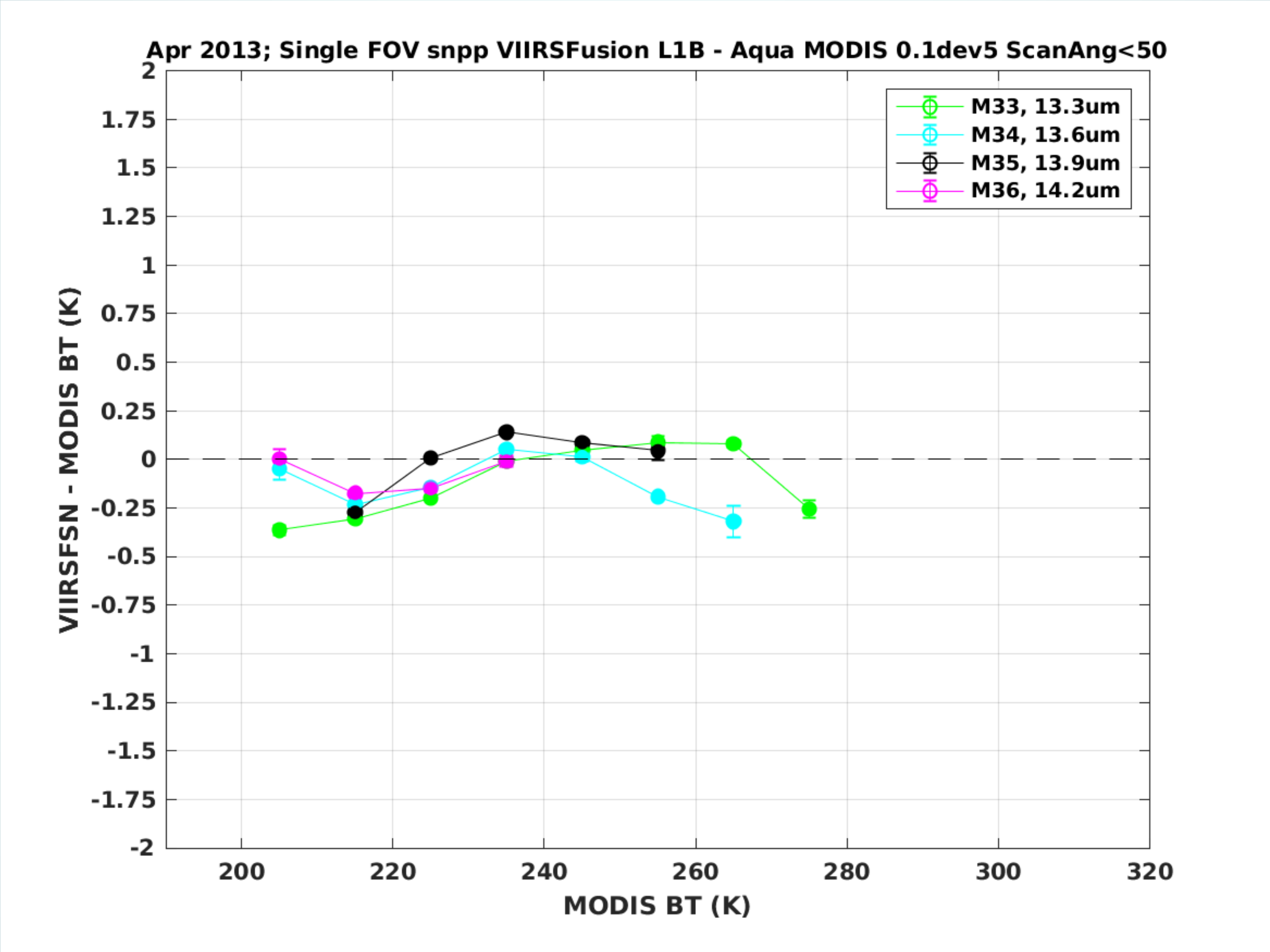
April 2013



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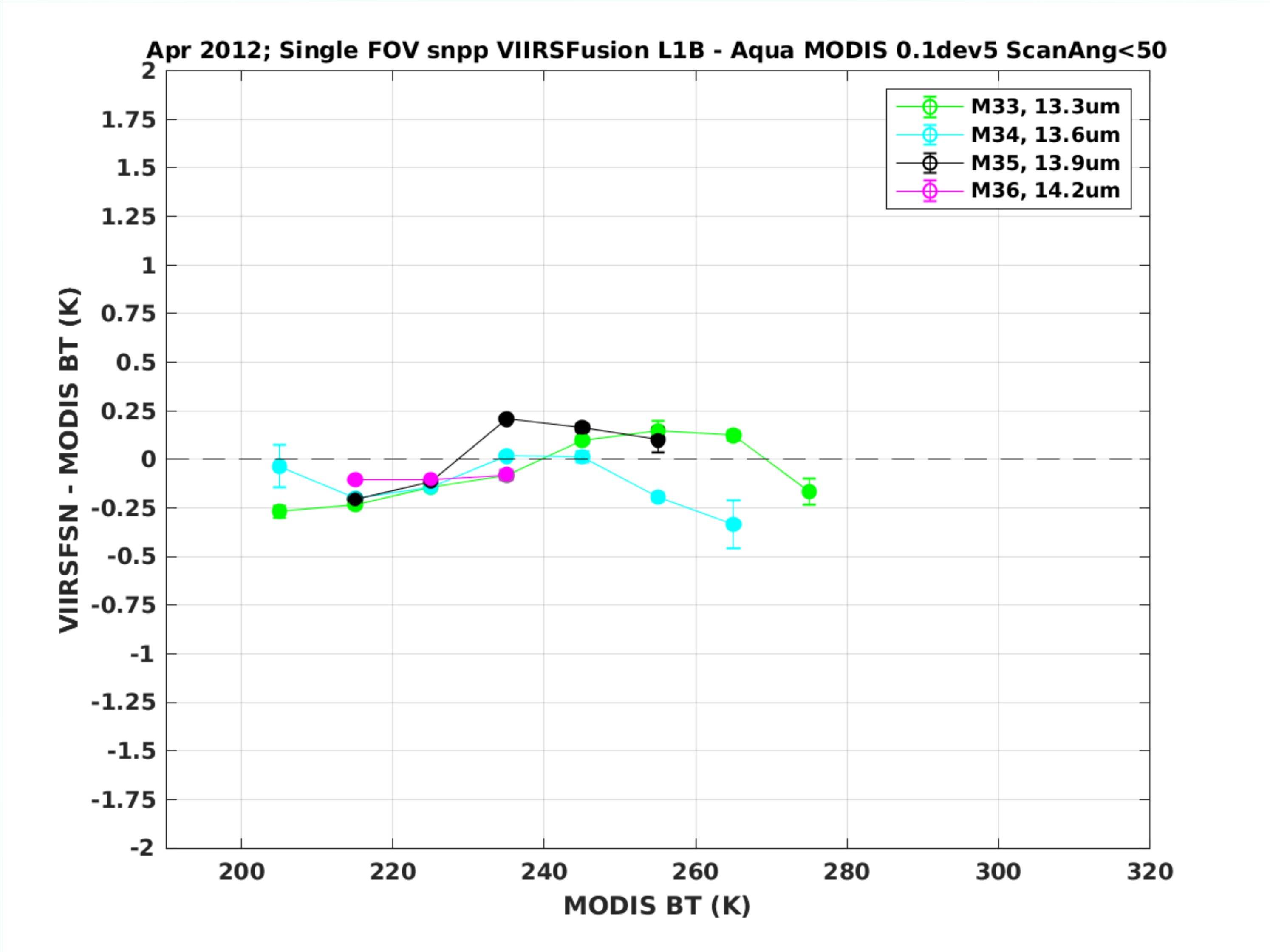
April 2012



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MODIS BT (K)
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
-1.25
-1.5
-1.75
-2
200
220
240
260
280
300
320

Impact on cloud property retrievals: Comparison with CALIPSO V4 products

Yue Li (SSEC/UW-Madison) and Andy Heidinger (NOAA)

Study employs CLAVR-x/ACHA (AWG Cloud Height Algorithm; AWG refers to the NOAA Algorithm Working Group)

ACHA adopts an optimal estimation approach

S-NPP analysis limited to one week of data in April 2018 and one week of data in October 2018

Collocations between VIIRS and CALIPSO assume time difference < 15 minutes and lat/lon difference < 4°

CALIOP cloud height adopted as the truth

Each CLAVR-x run produces different cloud mask, phase/type and cloud height products.

Li, Y., Baum, B. A., Heidinger, A. K., Menzel, W. P., and Weisz, E.: Improvement in cloud retrievals from VIIRS through the use of infrared absorption channels constructed from VIIRS-CrIS data fusion, *Atmos. Meas. Tech. Discuss*., https://doi.org/10.5194/amt-2019-497, in revision, 2020.

Cloud Phase Results - Daytime

No fusion: 1.6, 3.7, 8.5, 11, 12 μm channels

With fusion: 1.6, 3.7, **6.7**, 8.5, 11, 12, **13.3** μm channels

			CALIPSO/CALIOP		Percentage Agreement
			Ice	Liquid Water	
Suomi-NPP	With fusion	Ice	38.6	3.6	76.4
		Liquid Water	20	37.8	
	No fusion	Ice	34	2.4	73.8
		Liquid Water	23.8	39.8	

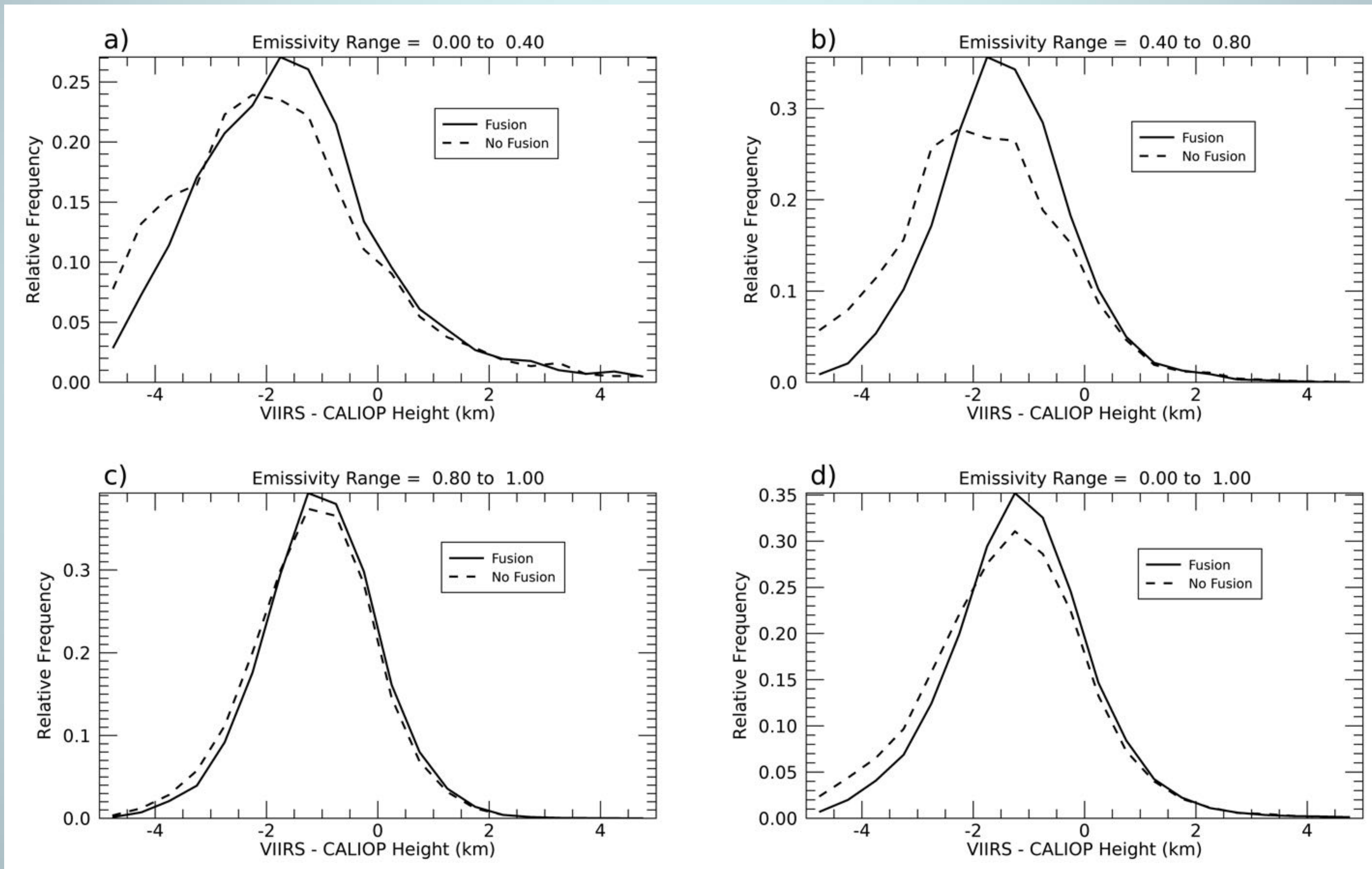
Cloud Phase Results - Nighttime

No fusion: 1.6, 3.7, 8.5, 11, 12 μm channels

With fusion: 1.6, 3.7, **6.7**, 8.5, 11, 12, **13.3** μm channels

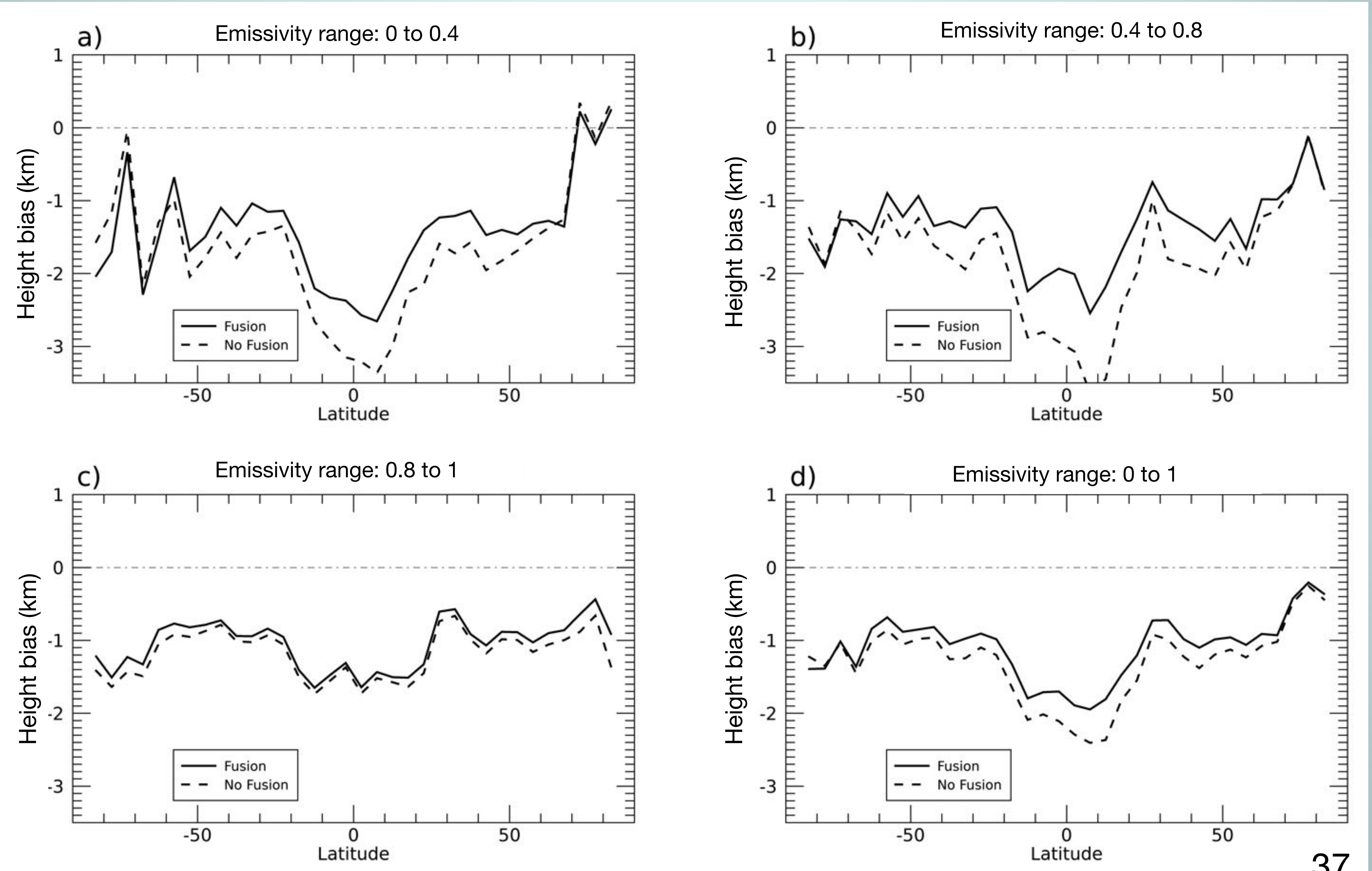
			CALIPSO/CALIOP		Percentage Agreement
			Ice	Liquid Water	
Suomi-NPP	With fusion	Ice	40.2	5.4	76
		Liquid Water	18.6	35.8	
	No fusion	Ice	37.8	4.6	74.6
		Liquid Water	20.8	36.8	

Suomi-NPP ACHA – CALIPSO comparisons for ice cloud heights
No fusion: 8.5, 11, 12 μm. *With fusion*: 8.5, 11, 12 & **13.3** μm



Zonal averages of S-NPP CTH differences (VIIRS-CALIOP) for ice clouds

No fusion: 8.5, 11, 12 μm. *With fusion*: 8.5, 11, 12 & **13.3** μm



Summary

The full records of the fusion product S-NPP and NOAA-20 are now available at the NASA LAADS DAAC:
https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion/

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23-25, 27, 28, 30–36) are provided in a VIIRS Level 2 granule (NetCDF4).

Also provide brightness temperature differences (VIIRS – VIIRS fusion) for M-bands 15 and 16 (split window); useful for uncertainty estimates

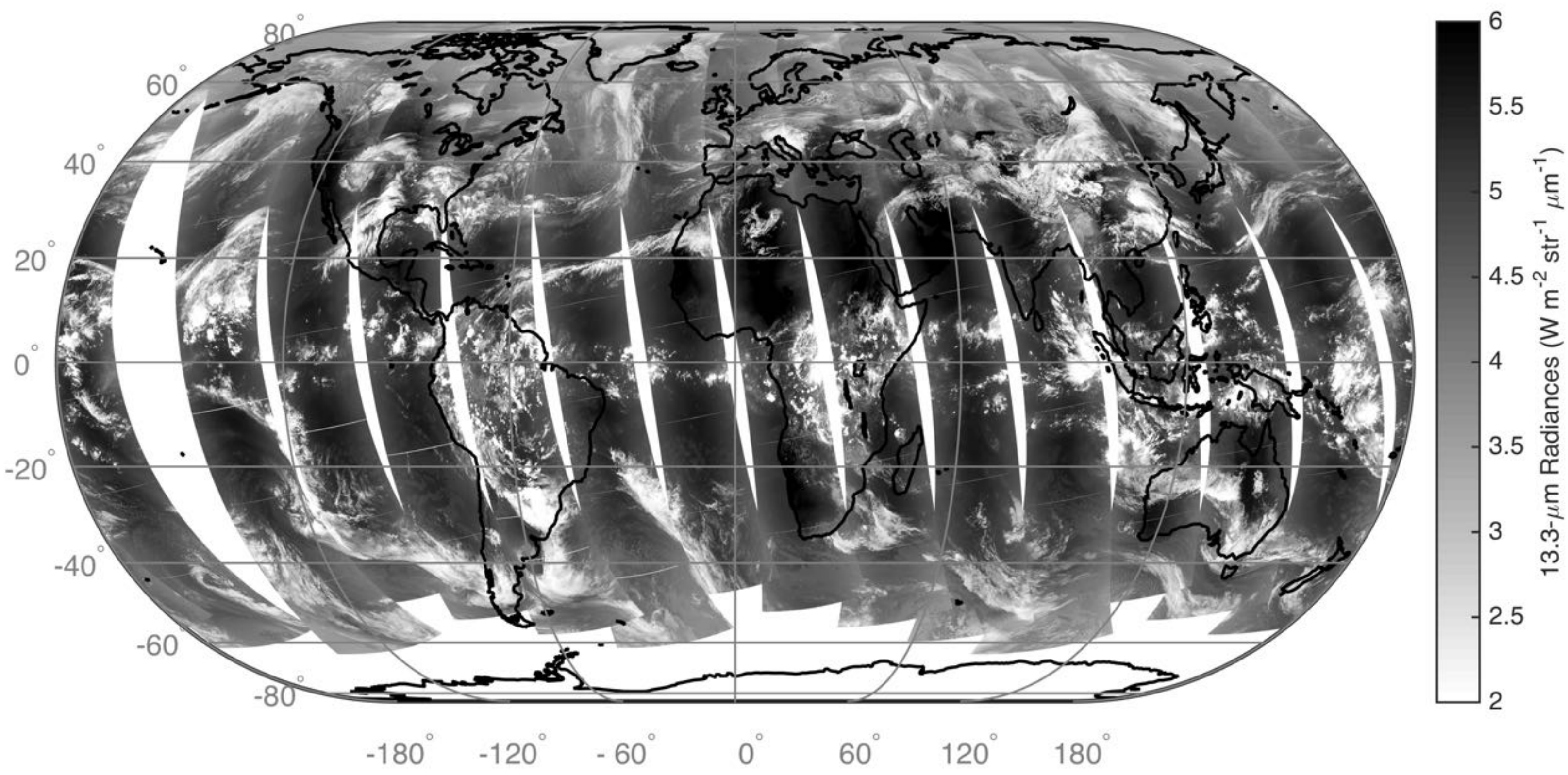
The VIIRS L2 granule is 6 minutes; very similar format to Level-1B

We would appreciate gaining community feedback on this product so that we can improve it!

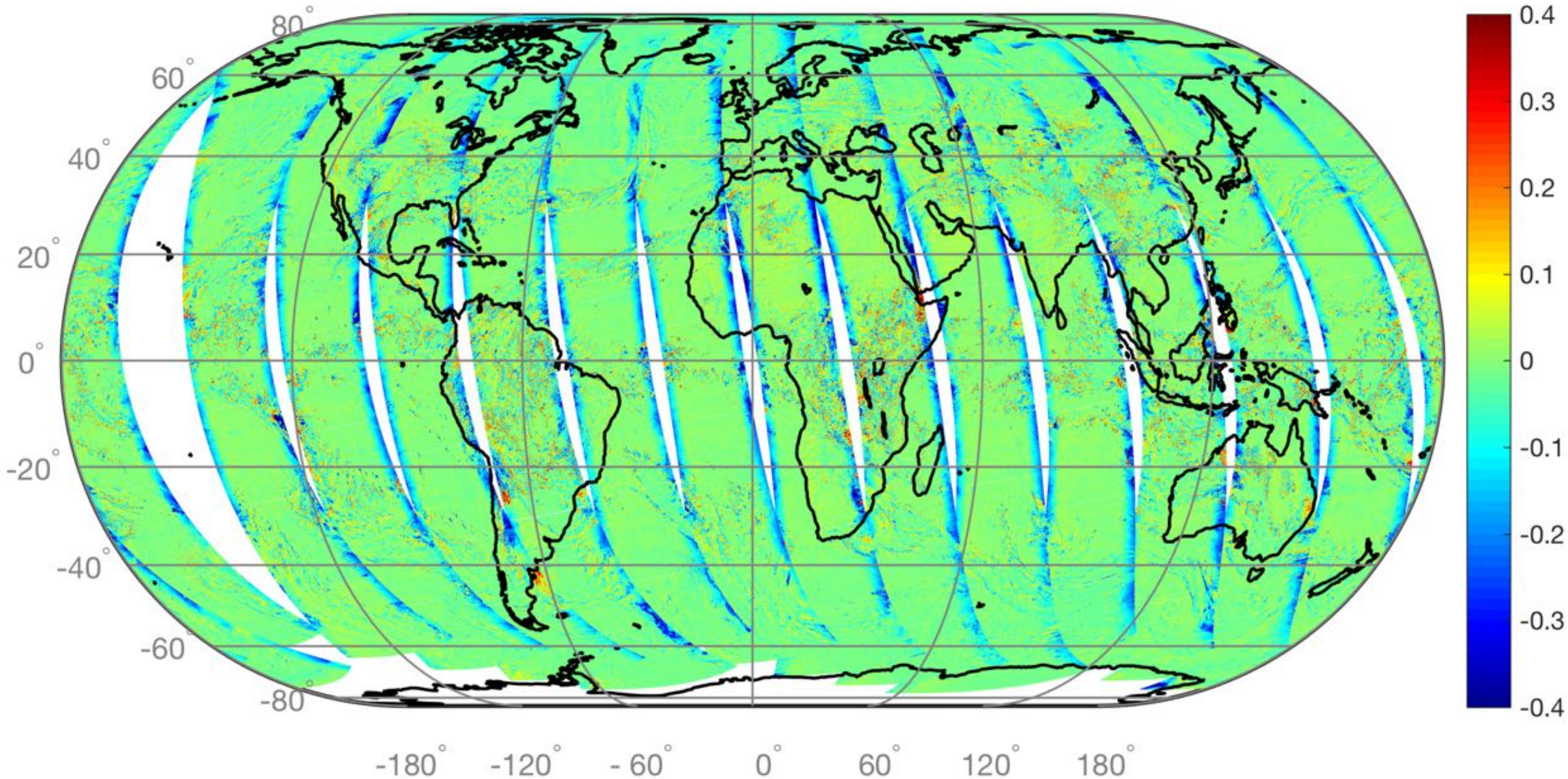
MODIS to MODIS+AIRS fusion comparison

Single day: April 17, 2015

Daytime Aqua MODIS measured 13.3-μm radiances
Full swath; 17 April, 2015



Radiance differences between measured and constructed (MODIS+AIRS fusion) 13.3-µm channel



There is no adjustment for atmospheric absorption outside the range of the sounder swath (high scan angles). Results are best within the sounder swath and degrade modestly outside of it.